Energy Research and Development Division
FINAL PROJECT REPORT

ENERGYIQ FOR ACTION-ORIENTED BENCHMARKING OF NON-RESIDENTIAL BUILDINGS

Prepared for: California Energy Commission
Prepared by: Lawrence Berkeley National Laboratory

OCTOBER 2014
CEC-500-2015-017

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Contract Number: 500-10-052

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ACKNOWLEDGEMENTS

This work was supported by the California Energy Commission's Public Interest Energy Research program and by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

EnergyIQ for Action-oriented Benchmarking of Non-residential Buildings is the final report for the National Lab Buildings Energy Efficiency Research Projects (contract number 500-10-052, work conducted by Lawrence Berkeley National Laboratory. The information from this project contributes to the Energy Research and Development Division's Buildings End-Use Energy Efficiency Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

This report documents results from the third phase of developing the *EnergyIQ* Action- oriented benchmarking tool. *EnergyIQ* has been very well received in the California marketplace, and beyond. The tool now has almost 1,300 registered users, who have collectively entered 900 buildings representing 130 million square feet of floor area. The *EnergyIQ* website had been visited more than 46,000 times (a four-fold increase since the close of Phase II) by over 25,000 individuals, viewing more than 150,000 pages of information (Figure 4). While California was the dominant source of traffic, visitors were also from the United States and 134 countries.

Technical accomplishments during this phase of work include:

1. Expanded functionality and user interface improvements: *EnergyIQ* now allows for new and more customized benchmarking techniques and more flexible peer group definitions. The underlying methods and robustness of the benchmarking process is also improved.

2. Improved infrastructure: The entire system has been ported to the Amazon cloud, resulting in higher reliability and lower hosting costs.

3. Licensed technology: The Application Program Interface (APIs) enabling third-party software developers to incorporate the *EnergyIQ* methods in derivative user interfaces have been improved.

4. Enhanced documentation: Improvements have been made to technical and tutorial documentation for users of the *EnergyIQ* user interface as well as for the API.

Highly effective and successful software and API services have been created and a large user base established. At least one other California Energy Commission research project—the Small and Medium Building Toolkit (PIR-12-031) —also relies on *EnergyIQ*.

Keywords: *EnergyIQ*, Action-oriented Benchmarking, Energy Use intensity, CEUS.

Please use the following citation for this report:

Mills, Evan. (Lawrence Berkeley National Laboratory). 2014. ***EnergyIQ for Action-oriented Benchmarking: Final Report.*** California Energy Commission. Publication number: CEC-500-2015-017.

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Introduction

Energy benchmarking is essential to the multi-faceted process of improving a building's energy efficiency. As practiced historically, benchmarking compares the energy intensity of a given building to similar buildings. During the design process, benchmarking can inform the establishment of efficiency targets based on how the best similar buildings perform.

Project Purpose

Traditional benchmarking techniques may reveal energy inefficiencies but provide no concrete guidance on how to improve performance. With sponsorship from the California Energy Commission, the Lawrence Berkeley National Laboratory is building and supporting the next generation of energy benchmarking methods to address this problem. *EnergyIQ* —the first "action-oriented benchmarking tool for non-residential buildings"—bridges the gap by providing a standardized assessment based on benchmarking results, along with decision-support information to help set and refine action plans. The tool is available at [http://*EnergyIQ*.lbl.gov].

Action-oriented benchmarking with *EnergyIQ* improves on simplified benchmarking processes. *EnergyIQ* benchmarks energy use, costs, and features for an array of building types and provides a carbon-emissions calculation for the energy consumed in the building, an important part of any businesses' overall "carbon footprint". The Energy IQ recommendations also help lay the groundwork for investment-grade audits and professional engineering calculations.

In addition to a free public-facing user interface, *EnergyIQ* provides a licensed web service and Applied Program Interface (API) (Appendix A). Through the API, third-party tool developers can tap the data and methods of *EnergyIQ* to implement on their own web sites or embed in energy management systems (Appendix B).

Project Results

The many functional enhancements made during this phase of the project were selected and prioritized based on the original market research conducted during previous phases of this project, as well as ongoing user feedback.

Interoperability: Users can now import their building data previously entered in the ENERGY STAR Portfolio Manager directly into *EnergyIQ*. This interoperability removes a large barrier for those using Portfolio Manager to deepen their assessments by graduating to *EnergyIQ*.

Improved peer-group definitions and filtering: New peer group choices are now available, including comparisons against other users of *EnergyIQ* or the users' own portfolios. The peer group composition can now be further refined, e.g., filtered by hours of occupancy, efficiency rating level or possession of an Energy Star rating, making peer group selections more relevant.

More metrics and features: New metrics allow for more informative benchmarking (e.g., energy use per employee or hotel bed rather than energy use per unit floor area). Added building characteristics enable users to identify more relevant upgrade recommendations.

Extended recommendations: Recommendations for non-California buildings have been added recognizing that those assessing California buildings whose responsibilities extend to buildings in other states will not be inclined to use *EnergyIQ* if it cannot be applied to their entire portfolio.

Improved Usability and Documentation: Many refinements were made to the user interface, and extensive documentation (including a User Guide and improved tooltips) was added. API documentation was considerably improved to foster technology transfer.

Infrastructure: The entire system has been moved to a cloud-based platform significantly improving performance and operating time (Appendix C).

A separate California Energy Commission project—the Small and Medium Building Efficiency Toolkit—also integrates *EnergyIQ* API for guiding users towards efficiency opportunities. This integration is done by benchmarking a building against similar buildings as the first step in the Small and Medium Building assessment.

Project Benefits

A diversity of companies and organizations have embraced and applied *EnergyIQ* to actual buildings across California and beyond. Almost 1,300 registered users have collectively entered 900 buildings representing 130 million square feet of floor area. The *EnergyIQ* website had been visited more than 46,000 times (a four-fold increase since the close of Phase II) by over 25,000 individuals, viewing more than 150,000 pages of information (Figure 3). While California was the dominant source of traffic, visitors came from the US and 134 countries. Leading users include:

- **Property Owners:** Alameda County, AT&T, Bank of America, Bloomberg, Cal EPA, Cisco, City of Hope, Glendale Community College, Lockheed Martin, Marriott, McDonalds, PwC, SDSU, Stanford Hospital, USC, Willis Tower
- **Real Estate:** CBRE, Cushman & Wakefield, Jones Lang LaSalle, Lutron, Time Equities
- **Equipment Manufacturers:** Honeywell, Johnson Controls, Philips, Siemens, Trane
- **A&E firms:** ARUP, CTG Energetics, EHDD, Heshong Mahone Group, Perkins+Will, Schneider Electric, Skanska, Taylor Engineering
- **Non-profits, program implementers, and research:** Booz Allen Hamilton, EnerNOC, Enovity, ICF International, Idaho National Laboratory, Lawrence Berkeley National Laboratory, Lucid, ESource, Navigant Consulting, New Buildings Institute, PECI, Pacific Northwest National Laboratory, Sandia National Lab, Stanford University, United States Green Building Council
- **Government:** California Air Resources Board, City of San Mateo
- **California Utilities:** PG&E, SCE, SCG, SDG&E, SMUD

There have been 32 signups to the API portal, 42 additional inquiries, and five licenses issued.

CHAPTER 1: Project Context and History

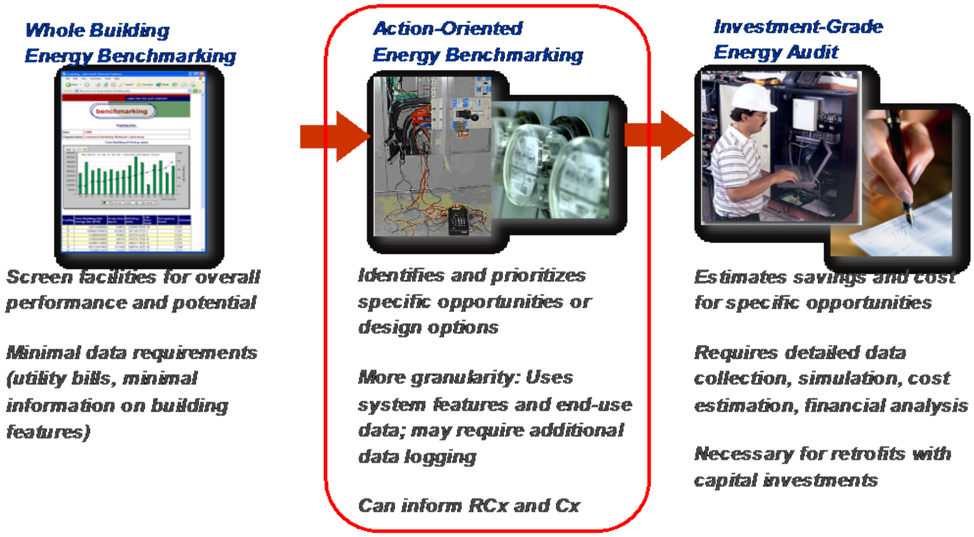
Energy benchmarking is essential to the multi-faceted process of improving the building's energy efficiency. It not only helps the parties responsible for a given building identify and implement energy saving opportunities, but can also help to understand how the building's performance compares to similar buildings. During the design process, benchmarking can inform the establishment of efficiency targets based on how the best similar buildings perform.

Benchmarking is increasingly important in the marketplace. As state and local governments promulgate requirements for energy use disclosure, benchmarking is needed to give meaning to this otherwise "raw" data. Market transactions such as real estate appraisals and sales, green insurance underwriting (Mills 2012), and energy audits all benefit from some form of benchmarking.

In isolation, traditional energy benchmarking does not provide practical guidance on how to improve energy efficiency. With sponsorship from the California Energy Commission (Energy Commission), Lawrence Berkeley National Laboratory (LBNL) is building the next generation of energy benchmarking methods to address this problem. *EnergyIQ*—the first "action-oriented" benchmarking tool for non-residential buildings—bridges this gap by providing a standardized opportunity assessment based on benchmarking results, along with decision-support information to help refine action plans. The tool is available at [http://*EnergyIQ*.lbl.gov].

Action-oriented benchmarking improves on simplified benchmarking processes by providing a low-effort bridge between limited whole-building benchmarks and investment-grade audits and professional engineering calculations (Figure 1). Whole-building benchmarks provide general context, but do not illuminate which end-uses or fuels may be particularly fertile candidates for intervention. At the other end of the spectrum, investment-grade audits are highly costly and many building owners will not make that expenditure decision with only whole-building benchmark results in hand.

Figure 1: Role of action-oriented benchmarking relative to whole building benchmarking and investment-grade energy audits



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The Energy Commission's Public Interest Energy Research Program originally conceived the *EnergyIQ* project, and sponsored subsequent development of the tool. California legislation calling for non-residential building energy use disclosure (AB1103)[1] was a strong driver for the original project, and the Energy Commission's perspective has been that while ENERGY STAR is the statutory "compliance" pathway, building owners should be encouraged to extend their analysis beyond the minimum requirements by using *EnergyIQ*. In conjunction with this, the Energy Commission's planned "AB1103 Portal" will provide links to both *EnergyIQ* and the statutory tool. *EnergyIQ* has been tailored to allow automated importing of user data from Portfolio Manager for just this reason. Similarly, utility-bill disclosure requirements under AB531[2] remove a barrier to benchmarking using systems like *EnergyIQ*.

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[1] Government Code sections 11346.9(a). AB 1103 (Stats. 2007, ch. 533, §2), codified in pertinent part in Public Resources Code, section 25402.10, requires owners of nonresidential buildings to disclose to prospective buyers, lessees, and lenders the previous twelve months of the building's energy use in advance of the sale of the building, or the leasing or financing of the entire building, and to "benchmark" that data by providing a comparison of the building's energy use to that of other similar buildings.

[2] An act to amend Section 25402.10 of the Public Resources Code, relating to energy. Existing law requires an owner or operator, on and after January 1, 2010, to disclose the United States Environmental Protection Agency's ENERGY STAR Portfolio Manager benchmarking data and rating to a prospective buyer, lessee of the entire building, or lender that would finance the entire building. The bill instead would require the owner or operator to disclose the benchmarking data and rating to a prospective buyer, lessee of the entire building, or lender that would finance the entire building based on a schedule of compliance established by the State Energy Resources Conservation and Development Commission.

EnergyIQ represents a major advancement beyond LBNL's widely used Cal-Arch (which it has replaced), providing a deeper level of analysis compared to more generalized whole-buildings tools such as the ENERGY STAR Portfolio Manager.

In developing *EnergyIQ*, LBNL surveyed potential users representing half a billion square feet of building floor area. LBNL also incorporated best practices recommended for energy benchmarking and tool design published by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE).

Development of *EnergyIQ* has proceeded under three phases of work. In Phase I, a conceptual design was developed, grounded in extensive focus groups and other methods of assessing the needs of target audiences. An initial web implementation was deployed with simplified functionality.

Phase II gathered feedback on the initial deployment and, based on the feedback, the site was modified to better serve user needs (Mills and Mathew 2012). The tool was not actively promoted, pending user testing and subsequent refinements. Major additional technical features were added in tandem with substantial investment in improving the usability and graphic design of the tool.

This report describes Phase III where additional key features were developed and the tool was formally launched. The APIs were released, allowing third-party developers to incorporate the analytics in other tools (Appendices A and B). The system was moved to a cloud-based infrastructure, allowing for high reliability and dynamic scalability to accommodate changes in user load (Appendix C).

A number of individuals and organizations have contributed to the development of *EnergyIQ.* The team includes technical staff from LBNL and elsewhere, as well as specialists in the design and usability of compelling web-based information tools:

- Evan Mills — Project lead — LBNL
- Paul Mathew — Analysis and Co-Leader — LBNL
- Andrea Mercado — Development Support, Testing, Customer Care — LBNL
- Bob Ramirez – iTron – Energy upgrade simulations
- William Bordass Associates and the Usable Buildings Trust — Advisors
- Chris Ralph & Robert Garcia — Programming and infrastructure — Bighead Technology (originally LBNL IT department)
- Kath Straub — Usability and information design — Usability.org
- Karen Fojas Lee — Visual design — Nomad Chique
- uTest – Acceptance testing

CHAPTER 2: *EnergyIQ*

2.1 Walkthrough

EnergyIQ benchmarks energy use, costs, and features for an array of building types and provides a carbon-emissions calculation for the energy consumed in the building, an important part of a building's overall "carbon footprint". The additional action-oriented benchmarking recommendations fundamentally improve on simplified benchmarking processes and help lay the groundwork for investment-grade audits and professional engineering calculations. The concepts and prototype implementation of *EnergyIQ* were documented in Phase 1 via two peer-reviewed publications (Mills et al., 2008; Mathew et al., 2008).

Figure provides a walkthrough of the main functionality and presentation of results. Figure 3 provides an illustration of application to the CEC headquarters. A variety of databases are incorporated within *EnergyIQ* from which users can specify peer groups for comparison. Using the tool, this data can be browsed visually and used as a backdrop against which to view a variety of energy benchmarking metrics for the user's own building. Users can save their project information and return at a later date to continue their exploration. The original database is the California Commercial End-Use Survey (CEUS), which provides details on energy use and characteristics for about 2800 buildings and 62 building types. CEUS is the most thorough survey of its kind ever conducted. National data from the Commercial Buildings Energy Consumption Survey (CBECS) were subsequently incorporated, allowing benchmarking across the country. As a service to users, users can import their building data from Environmental Protection Agency's Portfolio Manager.

The choice of metrics can strongly influence benchmarking findings. For example, energy use per seat versus per square foot in a restaurant may yield very different qualitative conclusions about efficiencies. With this in mind, *EnergyIQ* offers a wide array of easily selectable benchmark metrics, with visual as well as tabular display. These include energy, costs, greenhouse-gas emissions, and a large variety of physical characteristics (e.g., building components or operational strategies). The tool supports cross-sectional benchmarking for comparing the user's building to its peers at one point in time, as well as longitudinal benchmarking for tracking the performance of an individual building or enterprise portfolio over time.

Based on user inputs, the tool's "Act" module generates a list of opportunities and recommended actions, providing a range of savings for approximately 130 measures achieved by large-scale parametric analysis of similarly filtered CEUS buildings.[3] Measures focus on energy as distinct from load management or demand-response. Users can then explore various decision-support links for helpful information on how to refine action plans, create design-

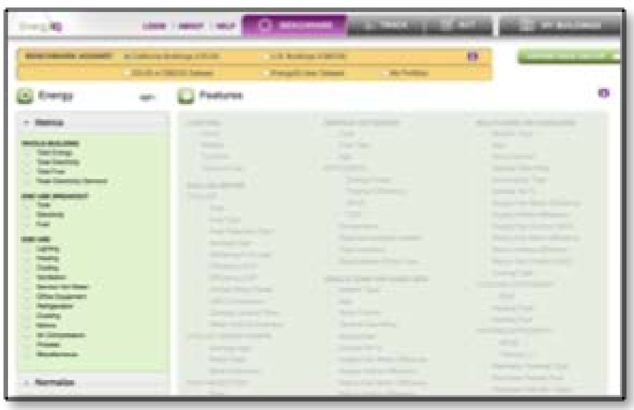
[3] Inputs and outputs are described here https://sites.google.com/a/lbl.gov/energyiq/

intent documentation, and implement improvements. This includes information on best practices, links to other energy analysis tools, and more.

Figure 2a-k:Key screenshots

(a)

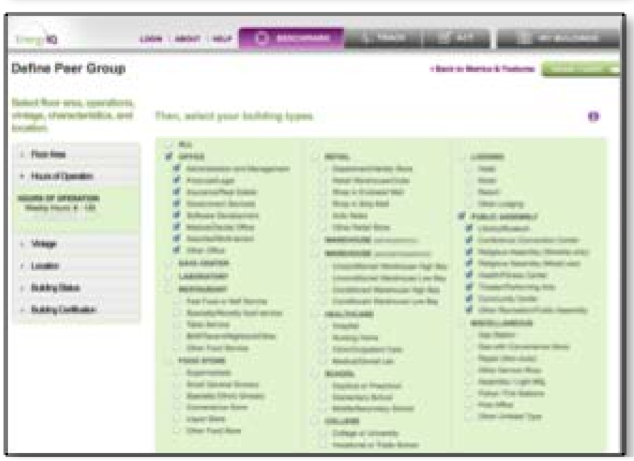
(b)



BENCHMARK:
Pick metrics or features

- Choose population to benchmark against (California; Other US locations)
- Benchmark energy or characteristics
- Choose metric, and normalization units (e.g., floor area, employees, hotel beds)
  - a) Whole building
  - b) By fuel

(c)



BENCHMARK:
Define peer group

- Filter by
  - a) floor area
  - b) hours of operation
  - c) vintage
  - d) location
  - e) certifications
- Choose any combination of 62 building types

CHARTS

- Choose among several benchmarking views…
    - ❑ Cross-sectional
    - ❑ Longitudinal (if multi-year data is entered)
- Add <u>**your**</u> building

(d)

(e)

(f)

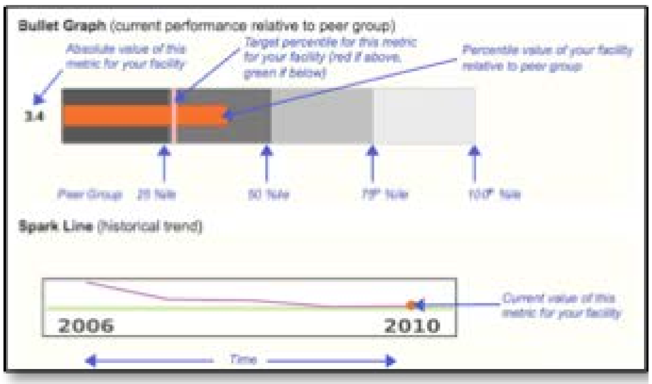
(g)

(h)

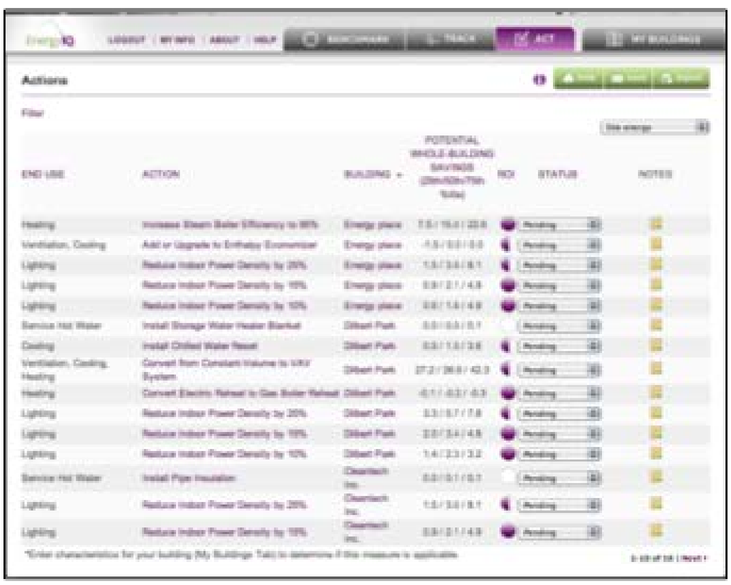
When choosing "Features" instead of energy benchmarks, an analysis is shown of the frequency of types of features (lighting, hvac, envelope, etc.) in the user-selected peer-group

(i)

(j)



(k)



TRACK:
Results Dashboard

- Benchmark vs peers
- Progress towards targets (if specified)
- Progress over time
- A wide range of metrics can be dislayed

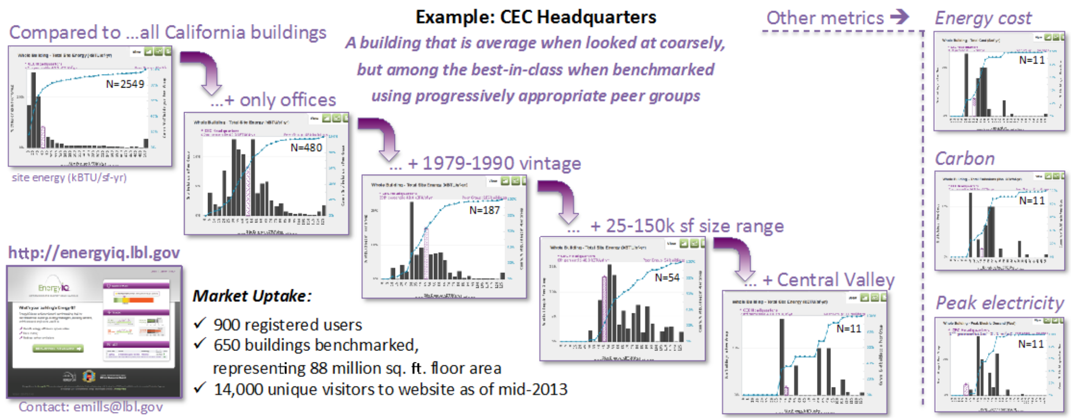
- Details on the "bullet graph" and "sparkline" styles

ACT:
Upgrade Recommendations

- 130 potentially applicable energy upgrades for each user building => 65k bldg+measure combinations

- Ranges of savings shown, based on simulation results for all peer-group buildings (California buildings only)

Figure 3. Illustration for the California Energy Commission headquarters.



Analysis of California Energy Commission headquarters performed using EnergyIQ.lbl.gov. The CEC building's location in the benchmark spectrum for each case is indicated by a hatched purple bar.

CHAPTER 3: Accomplishments in Phase III

During this project phase, an array of user-oriented improvements to *EnergyIQ*[4] were implemented. The LBNL team selected and prioritized the improvements based on the original market research conducted for this project, as well as ongoing user feedback.

Interoperability with other tools

- Users can now import building data that they have previously entered into the ENERGY STAR Portfolio Manager. Users requested this key feature, which, by eliminating the inefficiency of double entry, removes a significant barrier to prospective users of *EnergyIQ* who have already entered their data into Portfolio Manager.

Improved and more flexible peer group definitions

- Users can now benchmark their buildings against other users of *EnergyIQ* (previously, peer groups could only be drawn from the CEUS and CBECS databases).
- Users can now benchmark a single building exclusively against their own portfolio of buildings.
- Users can now associate their building with a larger number of buildings "features", which facilitates more accurate peer-group definitions.
- The peer group definition selection process is now much easier (including new slider bars for key inputs), allowing users to specify custom ranges (e.g., vintage bands) rather than pre-set bins.
- Users can now filter their peer groups by hours of occupancy for the California peer-group data set and occupancy and building ownership (private v government) for the US peer-group datasets (previously only size, vintage, and location). For benchmarking against other *EnergyIQ* users, additional filtering options include type of building certification (e.g. Energy Star, LEED, etc.) and whether a building exists or is in the design stage.

Improved benchmarking metrics and feature definitions

- A significantly expanded set of normalization options (new metrics) has been added to the tool. Initially, the only available metrics were energy (or carbon or cost) per square foot. Now users can also benchmark these quantities per employee for any building type, per seating for food service, per student for schools, per patient beds for hospitals, and per guest room for lodging building types.

Added feature specifications allow for the identification of more relevant upgrade recommendations.

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[4] A full list of updates is maintained at this web address: https://sites.google.com/a/lbl.gov/energyiq/re

More widely applicable recommendations

- Recommendations are now provided (in the "Act" tab) for buildings outside of California. While the Energy Commission's focus is on California, users often own or manage building portfolios spanning multiple states and won't invest their efforts in a tool like *EnergyIQ* unless it functions beyond the state's borders. One limitation of this new feature is that the non-California recommendations are just qualitative (a list of likely good measures); quantitative savings information is not included because the existing CEUS-based methodology is only appropriate for buildings located in California.

Improved user experience and documentation

- A significant number of improvements have been made to the user interface. These include creation of an on-line User Guide, as well as improved context-sensitive tooltips.[5]
- A downloadable input form is now offered, which makes it easier for users to assemble data before starting their web session.
- TheAPIs have been expanded to enable third-party software developers to incorporate the *EnergyIQ* methods in derivative user interfaces (Appendices A and B).[6]
- Documentation has been enhanced, both for users of the *EnergyIQ* user interface as well as for the API.
- Quality assurance was emphasized throughout development, which included third-party testing by uTest.com

Infrastructure and data enhancements

- The entire system has been moved to a cloud-based platform (using the Amazon Web Service, AWS), significantly improving performance and up-time.
- Source energy conversion factors have been updated.[7]

Communications & technology transfer

- *EnergyIQ* enjoyed some coverage in the trade press, which contributed to growth of traffic to the website (ACHRN 2013; Buildings Magazine 2013; EETD News 2013; ElectricityPolicy.com 2013; GreenBiz.com 2013).

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[5] See htps://sites.google.com/a/lbl.gov/energyiq/

[6] See https://developers.buildingsapi.lbl.gov/eiq/eiq-home

[7] See https://sites.google.com/a/lbl.gov/energyiq/methodology/conversion-factors

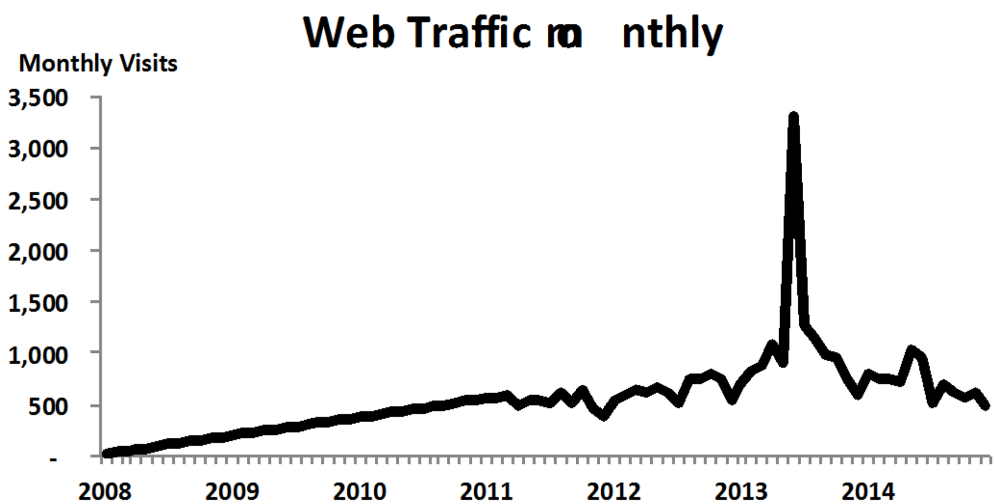
- A separate Energy Commission project—the Small and Medium Building (SMB) Efficiency Toolkit—now uses *EnergyIQ* for guiding users towards efficiency opportunities.
- The APIs were made available for third-party licensing.

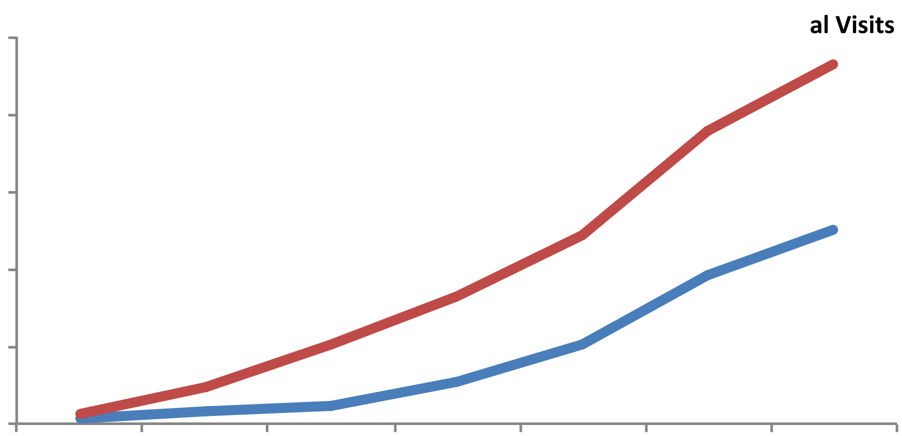
CHAPTER 4: Market Impact

4.1 Usage of the Tool

As of August 2014, the *EnergyIQ* website had been visited more than 46,000 times (a four-fold increase since the close of Phase II) by over 25,000 individuals, viewing more than 150,000 pages of information (Figure 4a-b). While California was the dominant source of traffic, visitors came from across the US and from 134 other countries.

Figure 4a-b: The *EnergyIQ* Website Traffic





All visitors can use *EnergyIQ* to examine the peer-group data, applying filtering and visualization conventions of their choosing. Users who wish to compare their own buildings to the peer groups must register and open a no-cost account. As of August 2014, almost 1,300 users had registered. These users had entered 900 buildings, representing 130 million square feet of floor area. Figures 5a-b illustrate some key characteristics (vintage and floor area) of users' buildings.

Figure 5a-b: *EnergyIQ* users represent a range of building types and characteristics

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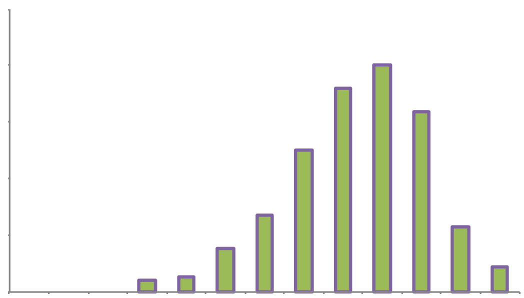

Among the leading users of *EnergyIQ* are:

- **Property Owners:** Alameda County, AT&T, Bank of America, Bloomberg, Cal EPA, Cisco, City of Hope, Glendale Community College, Lockheed Martin, Marriott, McDonalds, PwC, SDSU, Stanford Hospital, USC, Willis Tower
- **Real Estate:** CBRE, Cushman & Wakefield, Jones Lang LaSalle, Lutron, Time Equities
- **Equipment Manufacturers:** Honeywell, Johnson Controls, Philips, Siemens, Trane
- **A&E firms:** ARUP, CTG Energetics, EHDD, Heshong Mahone Group, Perkins+Will, Schneider Electric, Skanska, Taylor Engineering
- **Non-profits, program implementers, and research:** Booz Allen Hamilton, EnerNOC, Enovity, ICF International, Idaho National Laboratory, Lawrence Berkeley National Laboratory, Lucid, ESource, Navigant Consulting, New Buildings Institute, PECI, Pacific Northwest National Laboratory, Sandia National Lab, Stanford University, United States Green Building Council
- **Government:** California Air Resources Board, City of San Mateo
- **California Utilities:** PG&E, SCE, SCG, SDG&E, SMUD

4.2 Interest in the APIs

As of August 2014 there had been 32 signups to the API portal, and 42 additional inquiries. Five licenses have been issued. The remaining parties should be pursued if subsequent phases of work are approved.

CHAPTER 5: The Future of *EnergyIQ*

5.1 Recurring Supporting and Maintenance Needs

Unlike ordinary technology development or the preparation of written reports, software projects bear ongoing costs even without adding new features. For *EnergyIQ*, these expenses include core administration, user support, updates as new data become available, and unexpected requirements to adapt to third-party APIs upon which the software depends.

Core administrative costs include monthly fees that must be paid for web hosting and server administration in the highly reliable but sometimes complicated cloud-based hosting system. As new versions of software browsers are released, websites invariably have to adapt so as to remain functional. Lastly, as with any software product, bugs are periodically identified and must be addressed.

There are two types of users (1) users of the *EnergyIQ* .lbl.gov website, and (2) users of the APIs. API users are particularly sophisticated and demanding as they are also software developers and often have highly technical and time-sensitive needs. While current use of the API is minimal, lack of the ability to support new users undermines the underlying technology transfer premise of the project. Certain data become outdated (e.g. energy prices) and need to be kept current. They underlying CEUS data will also become outdated if and when the Energy Commission updates that survey.

Interoperability with EPA's Portfolio Manager provides substantial value to *EnergyIQ* users (greatly reducing the cost of entering building data), but EPA unpredictably updates their API in ways that impose significant adaptation costs on its users, including LBNL. The project is currently confronted with such an update, and LBNL anticipates more such changes in the near future, which in lieu of resources to adapt will necessitate the discontinuation of the Portfolio Manager interoperability.

5.2 Future Development Opportunities

While *EnergyIQ* is fully functional, many opportunities have been identified by users and other parties for improvement. Examples include:

Functionality

- Incorporating three of the latest features into the API so that third-party software developers can easily employ them.
- Creation of a user group / social network so that users can exchange experiences and ideas.
- Expand peer groups by incorporating data from other Energy Commission/LBNL benchmarking projects into EIQ. A key under-represented group is data centers.
- Add more contemporary data visualizations.
- Incorporate exemplary buildings as reference points on benchmark charts.
- Implement "Green Button" to greatly facilitate user data entry.
- User-determined inclusion of selected buildings in Portfolio; groupings of buildings, using "tagging" method.
- Facilitate analysis and messaging of zero-net buildings.
- Further tasks in support of Energy Commission programs and policy objectives (e.g., related to AB 1103 and AB 758)

Infrastructure

- Recode system in PHP for easier debugging and future development. PHP is a popular general-purpose scripting language that is especially suited to web development.
- Eliminate "stored procedures" in current database. This greatly complicates development.
- Shift from Oracle database to MySQL for improved performance and lower hosting costs
- Enable *EnergyIQ* to utilize its own APIs (Graphical User Interface is currently "hard coded")

Ongoing outreach is needed to grow the user base and make potential licensees of the APIs aware of the offering.

5.3 Technology transfer and commercialization

The underlying *EnergyIQ* technology is comprised of algorithms for computing meaningful building energy metrics, data-visualization rules, an Internet platform for providing target-audience access to the technology, and a web-based graphical user interface (GUI) for presenting the information. An additional leg of the technology transfer strategy is to make our energy engineering methods transparent, such that others can replicate them. This documentation is organized in a publicly accessible wiki.[8]

[8] https://sites.google.com/a/lbl.gov/energyiq/

Thus, technology transfer initially takes the form of *EnergyIQ* being accessed by individuals who influence energy decisions in non-residential buildings. As noted above, user uptake has been significant. The site has been available at no charge to users.

EnergyIQ has achieved commercialization, but not the traditional sense. Improving on the old paradigm of stove-piped software development and transfer of code to a private-sector entity, the "product" is an API that can be used by private software developers to develop novel user interfaces around unique business models (Mills and Mathew 2012b). This "hybrid" strategy allows the sponsor and developer (Energy Commission and LBNL) to host and maintain a user interface that is consistent with policy and programmatic goals, without precluding variants that serve other entities' strategic goals.[9]

The advantages of the API approach are multifold:

- It speeds and simplifies syndication of models and databases, thus contributing to innovation in the marketplace.
- It radically lowers the cost of entry for private software developers.
- Developers can focus more on front-end development, allowing far more vibrant spin-off scenarios, as the costs of market entry are vastly lowered.
- It facilitates more internal consistency in methodology and data across proliferation of tools.
- It ameliorates the sometimes contentious separation between "public" and "private" tools.

Moreover, in contrast to the full spinoff approach, with APIs the tool creators and funders mitigate the risk of recipients going out of business or otherwise "mothballing" the code, which is a long-standing problem for sponsors of energy software R&D.

Given the replication potential of this offering, technology transfer via APIs promises to reach even more people than LBNL's own GUI. There have thus far been 32 signups to the API portal, and 42 additional inquiries. Five licenses have been issued (Appendix C). The California Air Resources Board has already initiated using *EnergyIQ* within its CoolCalifornia carbon footprint tool and the API is being used to support an unrelated Energy Commission project seeking to develop a tool for identifying upgrade opportunities in commercial buildings.

5.4 Sustainability Challenges in Maintaining the *EnergyIQ* Service for the Marketplace

An intrinsic dilemma in any public-goods software development project is the one-time development investment juxtaposed against ongoing maintenance of the service and support of long-term users. Software is a service more than a "product" in the static sense of the term, and thus intrinsically requires a regular infusion of resources. At least one other Energy Commission project also depends on *EnergyIQ.*

[9] https://developers.buildingsapi.lbl.gov/eiq/eiq-home

Developing and hosting of APIs has radically lowered the costs of market entry for software developers seeking to offer energy benchmarking tools. While the APIs offer potential for third parties to establish dominant web presences that could, in principal, make the Energy Commission-hosted user interface obsolete, this has not yet occurred. Even were it to occur, the underlying API requires maintenance.

Complete spin-off to the private sector does not appear compatible with Energy Commission requirements because the underlying CEUS data are highly confidential and protected by Energy Commission policy. The Energy Commission would not allow the delivery of that data to third parties. Only LBNL, or another entity so empowered by the Energy Commission, can maintain *EnergyIQ* under these circumstances.

This project created a highly effective and successful software and API services; however, it cannot be maintained without funding to continue providing ongoing support. LBNL desires to maintain this service for the 1,300 current users and new users who join almost daily. Other entities (e.g., U.S. Department of Energy as well as private-sector organizations) have been approached but no one has yet signaled being prepared to assume stewardship of the service from the Energy Commission.

GLOSSARY

Term	Definition
API	Application Program Interface
CBECS	Commercial Building Energy Consumption Survey
CEUS	Commercial End Use Survey
Energy Commission	California Energy Commission
EPIC	Electric Program Investment Charge
GUI	Graphical User Interface
LBNL	Lawrence Berkeley National Laboratory
RD&D	Research Development and Deployment
Smart Grid	Smart Grid is the thoughtful integration of intelligent technologies and innovative services that produce a more efficient, sustainable, economic, and secure electrical supply for California communities.

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Mills, Evan and Paul Mathew. 2014. "Monitoring-Based Commissioning: Benchmarking Analysis of 24 University Buildings in California," Energy Engineering 111(4):7-24 http://evanmills.lbl.gov/pubs/pdf/mbcx-mills-mathew-energy-engineering.pdf

APPENDIX A:
EIQ Final Report Figures

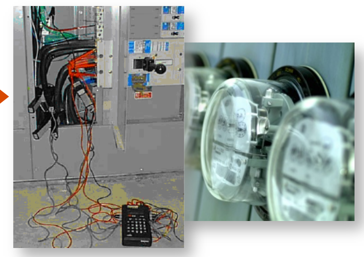
gure 1

Whole Building Energy Benchmarking

Screen facilities for overall performance and potential

Minimal data requirements (utility bills, minimal information on building features)

Action-Oriented Energy Benchmarking



Identifies and prioritizes specific opportunities or design options

More granularity: Uses system features and end-use data; may require additional data logging

Can inform RCx and Cx

Investment-Grade Energy Audit

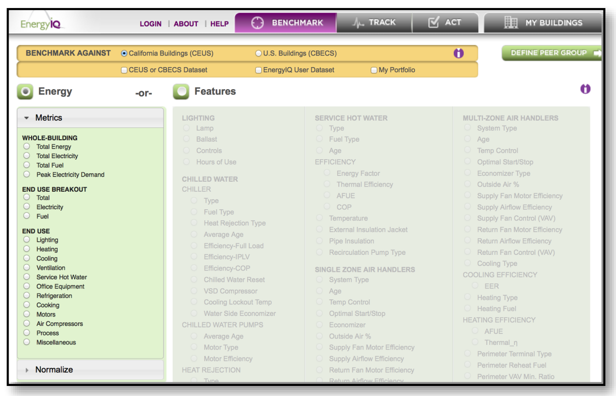
Estimates savings and cost for specific opportunities

Requires detailed data collection, simulation, cost estimation, financial analysis

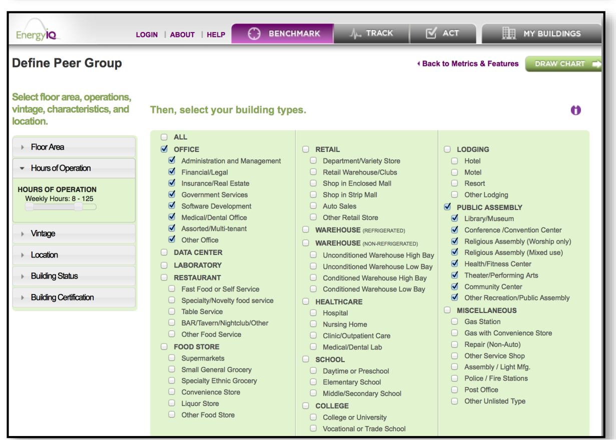
Necessary for retrofits with capital investments gure 2a-c

(a)

(b)



(c)



BENCHMARK:
Pick metrics or features

- Choose population to benchmark against (California; Other US locations)
- Benchmark energy or characteristics
- Choose metric, and normalization units (e.g., floor area, employees, hotel beds)
  - a) Whole building
  - b) By fuel

BENCHMARK:
Define peer group

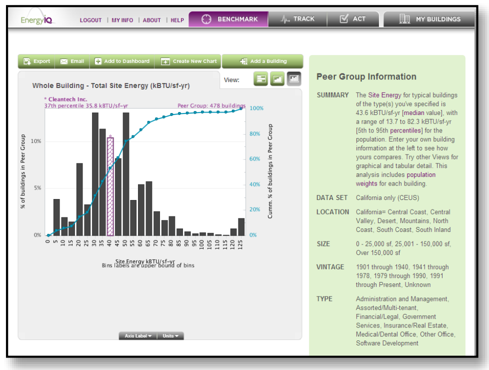
- Filter by
  - a) floor area
  - b) hours of operation
  - c) vintage
  - d) location
  - e) certifications
- Choose any combination of 62 building types

gure 2d-h

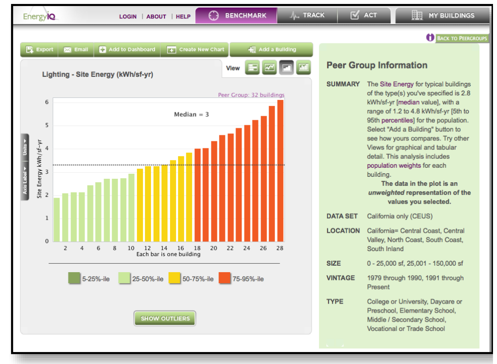
CHARTS

- Choose among several benchmarking views…
  - ❑ Cross-sectional
  - ❑ Longitudinal (if multi-year data is entered)
- Add **<u>your</u>** building

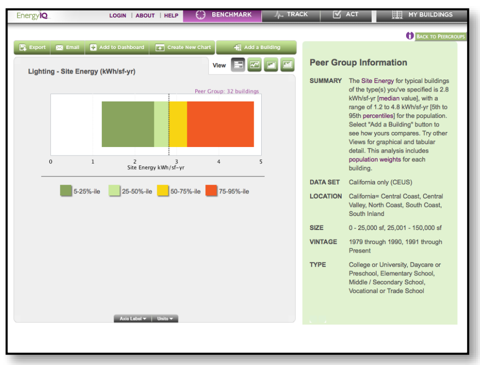
(d)



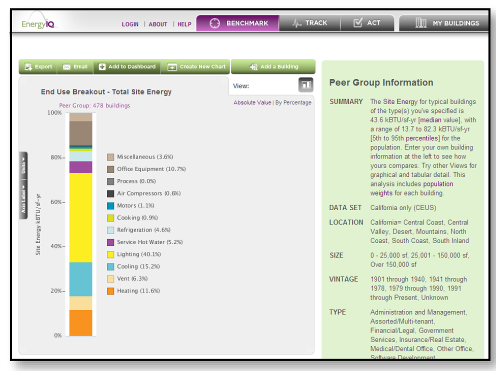
(e)



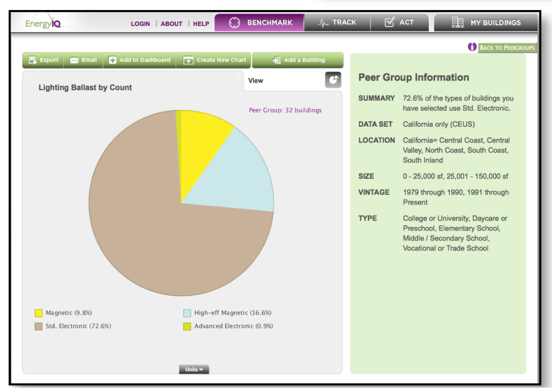
(f)



(g)



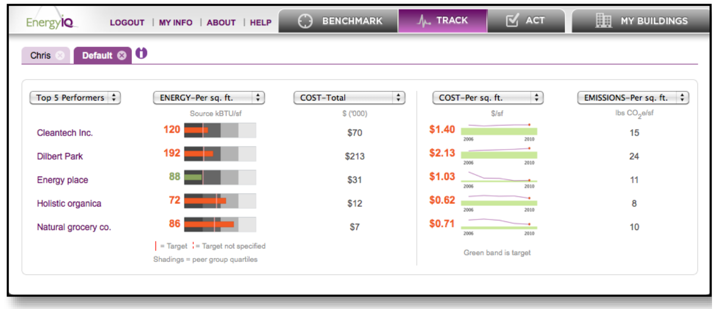
(h)



When choosing "Features" instead of energy benchmarks, an analysis is shown of the frequency of types of features (lighting, hvac, envelope, etc.) in the user-selected peer-group

gure 2i-k

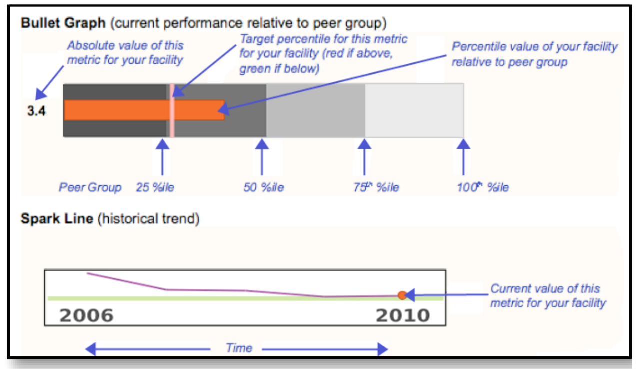
(i)



TRACK:
Results Dashboard

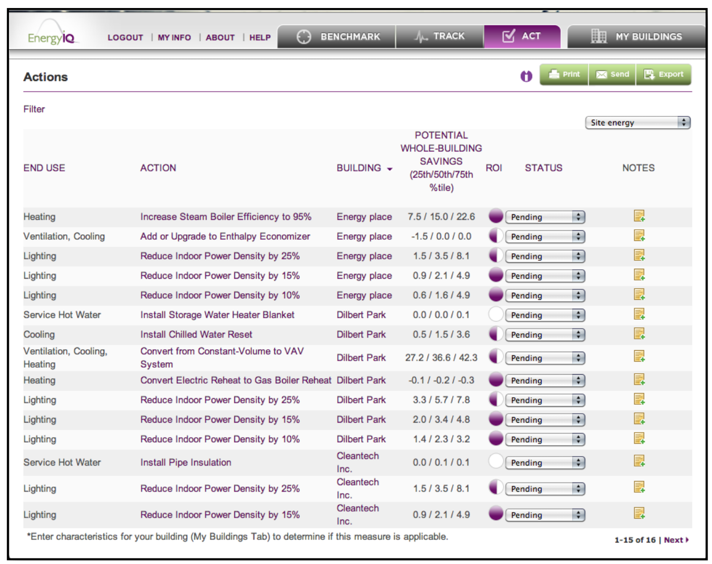
- Benchmark vs peers
- Progress towards targets (if specified)
- Progress over time
- A wide range of metrics can be dislayed

(j)



- Details on the "bullet graph" and "sparkline" styles

(k)

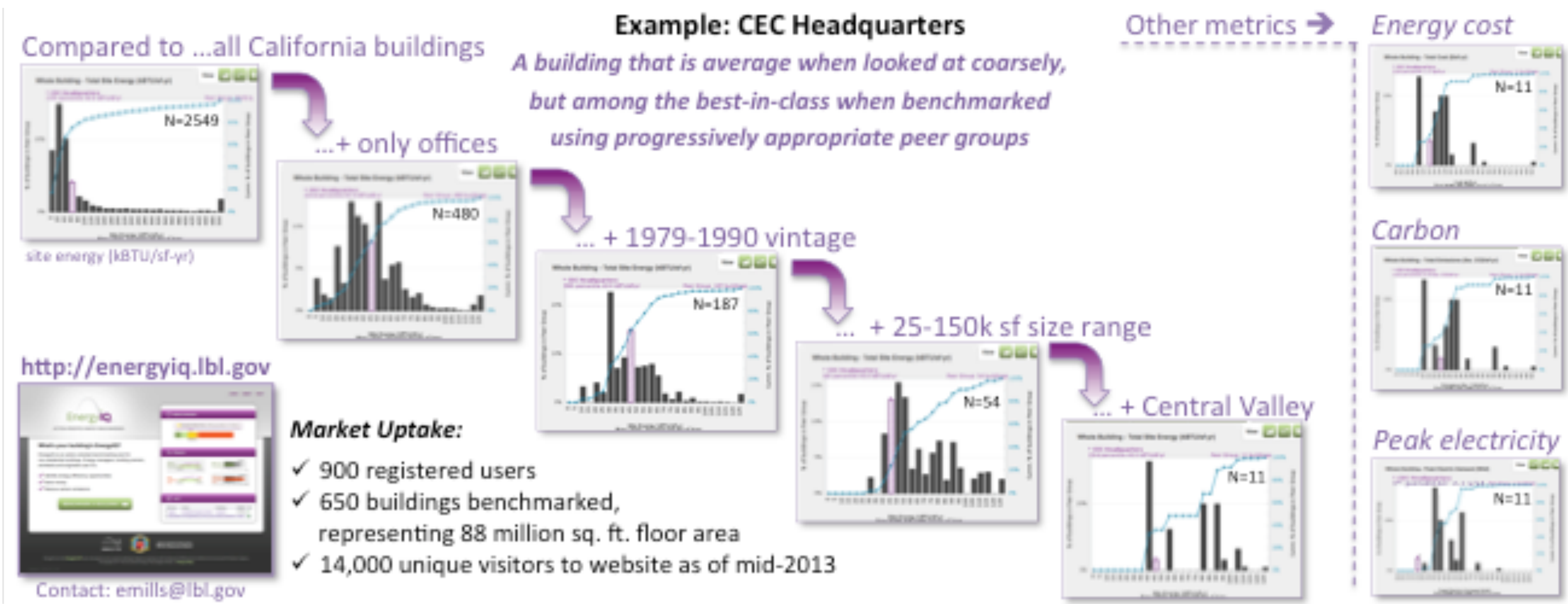


END USE	ACTION	BUILDING	POTENTIAL WHOLE-BUILDING SAVINGS (25th/50th/75th %ile)	ROI	STATUS	NOTES
Heating	Increase Steam Boiler Efficiency to 95%	Energy place	7.5 / 15.0 / 22.6		Pending	
Ventilation, Cooling	Add or Upgrade to Enthalpy Economizer	Energy place	-1.5 / 0.0 / 0.0		Pending	
Lighting	Reduce Indoor Power Density by 25%	Energy place	1.5 / 3.5 / 8.1		Pending	
Lighting	Reduce Indoor Power Density by 15%	Energy place	0.9 / 2.1 / 4.9		Pending	
Lighting	Reduce Indoor Power Density by 10%	Energy place	0.6 / 1.6 / 4.9		Pending	
Service Hot Water	Install Storage Water Heater Blanket	Dilbert Park	0.0 / 0.0 / 0.1		Pending	
Cooling	Install Chilled Water Reset	Dilbert Park	0.5 / 1.5 / 3.6		Pending	
Ventilation, Cooling, Heating	Convert from Constant-Volume to VAV System	Dilbert Park	27.2 / 36.6 / 42.3		Pending	
Heating	Convert Electric Reheat to Gas Boiler Reheat	Dilbert Park	-0.1 / -0.2 / -0.3		Pending	
Lighting	Reduce Indoor Power Density by 25%	Dilbert Park	3.3 / 5.7 / 7.8		Pending	
Lighting	Reduce Indoor Power Density by 15%	Dilbert Park	2.0 / 3.4 / 4.8		Pending	
Lighting	Reduce Indoor Power Density by 10%	Dilbert Park	1.4 / 2.3 / 3.2		Pending	
Service Hot Water	Install Pipe Insulation	Cleantech Inc.	0.0 / 0.1 / 0.1		Pending	
Lighting	Reduce Indoor Power Density by 25%	Cleantech Inc.	1.5 / 3.5 / 8.1		Pending	
Lighting	Reduce Indoor Power Density by 15%	Cleantech Inc.	0.9 / 2.1 / 4.9		Pending	

ACT:
Upgrade Recommendations

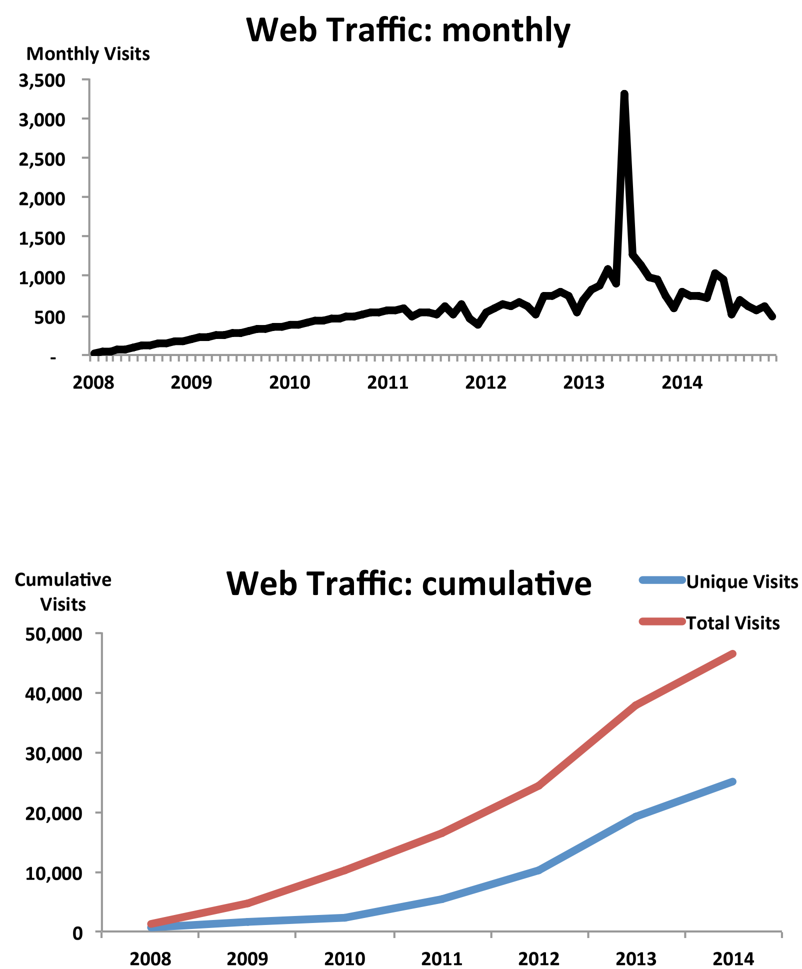
- 130 potentially applicable energy upgrades for each user building => 65k bldg+measure combinations
- Ranges of savings shown, based on simulation results for all peer-group buildings (California buildings only)

gure 3

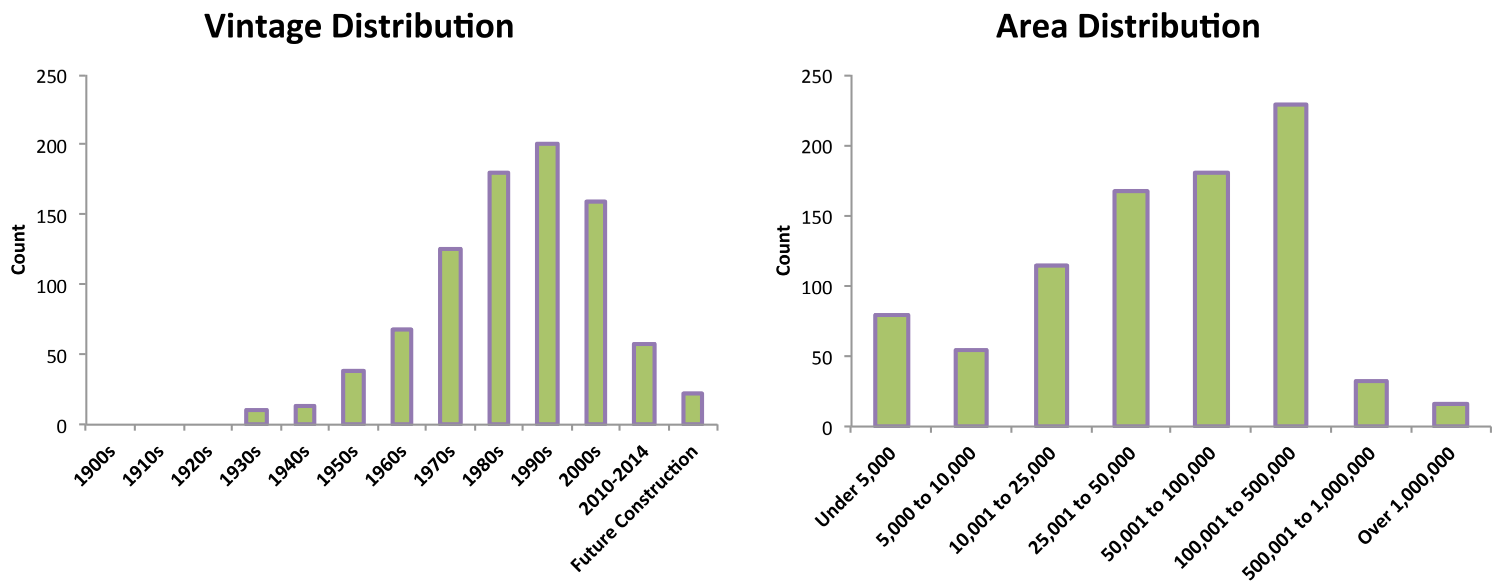


Example: CEC Headquarters
A building that is average when looked at coarsely,
but among the best-in-class when benchmarked
using progressively appropriate peer groups
Compared to ...all California buildings
N=2549
site energy (kBTU/sf-yr)
...+ only offices
N=480
... + 1979-1990 vintage
N=187
... + 25-150k sf size range
N=54
... + Central Valley
N=11
Other metrics
Energy cost
N=11
Carbon
N=11
Peak electricity
N=11
http://energyiq.lbl.gov
Contact: emills@lbl.gov
Market Uptake:
✓ 900 registered users
✓ 650 buildings benchmarked,
representing 88 million sq. ft. floor area
✓ 14,000 unique visitors to website as of mid-2013

gure 4a-b


Web Traffic: monthly
Monthly Visits
3,500
3,000
2,500
2,000
1,500
1,000
500
-
2008
2009
2010
2011
2012
2013
2014
Web Traffic: cumulative
Cumulative Visits
50,000
40,000
30,000
20,000
10,000
0
2008
2009
2010
2011
2012
2013
2014
Unique Visits
Total Visits

gure 5a-b



Vintage Distribution
Count
250
200
150
100
50
0
1900s
1910s
1920s
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s
2010-2014
Future Construction
Area Distribution
Count
250
200
150
100
50
0
Under 5,000
5,000 to 10,000
10,001 to 25,000
25,001 to 50,000
50,001 to 100,000
100,001 to 500,000
500,001 to 1,000,000
Over 1,000,000